

FIRE EVACUATION BY ELEVATORS

by John H. Klote, Scot P. Deal, Edward A. Donoghue, Bernard M. Levin and Norman E. Groner

THERE IS A RISING CONCERN FOR THE SAFETY of persons from fire who cannot travel building emergency exit routes in the same manner or as quickly as expected of able persons. One proposed solution for providing safety for these people is the use of elevators. However, today's elevators are not intended as means of fire egress and they should not be used for fire evacuation (Sumka, 1988).

The idea of using elevators to speed up fire evacuation and to evacuate persons with disabilities has gained considerable attention (Bazjanac, 1974; Bazjanac, 1977; Pauls, 1977). On February 19-20, 1991, the American Society of Mechanical Engineers (ASME) held a symposium in Baltimore entitled "Fire and Elevators." Several of the papers at this symposium dealt with fire evacuation by elevators (Degenkolb, 1991; Fox, 1991; Gatfield, 1991; Klote and Tamura, 1991; Pauls, Gatfield and Juillet, 1991).

In New Orleans on May 20, 1992, the National Fire Protection Association (NFPA) held a panel session on "Use of Elevators in High-Rise Buildings During Fire Emergencies." Several participants at the NFPA session noted changes in ideas and attitudes since the ASME symposium. A workshop on "Elevator Use During Fires" was held at the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland on September 29, 1992. Because ideas on this topic are progressing quickly, ASME has plans in the works for another symposium in a year or so.

This article is about the NIST workshop, which consisted of presentations and an open discussion. The presentations were about NIST elevator research by John H. Klote, human considerations by Bernard M. Levin and Norman E. Groner, and industry concerns by Edward A. Donoghue.

NIST Elevator Research

Elevator Smoke Control

Field tests of elevator pressurization systems (Schmidt and Klote, 1982; Klote, 1983; Klote, 1984), funded by the U.S. Department of Veterans Affairs, showed that elevator pressurization systems designed to prevent smoke flow through elevator shafts (hoistways) were not appropriate for the smoke protection of elevators intended for fire evacuation.

To develop information about elevator smoke control for fire evacuation, a joint project between NIST and the National Research Council of Canada (NRCC) was established. This joint project included the following:

- a) the development of elevator smoke control system concepts (Klote and Tamura, 1986a);
- b) a theoretical and experimental study developed an approach for designing elevator smoke control systems to withstand the pressure fluctuations produced by the motion

of elevator cars (Klote and Tamura, 1986b, 1987; Klote, 1988);

c) verification of the system concepts by a series of full-scale fire tests in the 10-story fire tower near Ottawa (Tamura and Klote, 1987a, 1987b, 1988).

Based on the above research, design information for elevator smoke control was developed (Klote and Tamura, 1991). This design information is also incorporated in the revised smoke control manual (Klote and Milke, 1992).

Elevator Evacuation Project

The General Services Administration (GSA) funded a project to study the feasibility of elevator evacuation systems for office buildings and to develop design considerations. The focus of this project was the use of elevators to evacuate the general population during fire emergencies. The project included evacuation of people with disabilities and the use of stairs in combination with elevators. The elevators need protection from heat, smoke and water. Such protected elevators would facilitate fire service rescue and mobilization.

This project addressed system concepts, goals, objectives, engineering considerations, human considerations, calculation of evacuation time and potential applications. The following sections address the water problem, calculation of evacuation time and potential applications of elevator evacuation.

For more detailed information about this elevator evacuation study, readers are referred to the final report of this project (Klote, Alvord, Levin and Groner, 1992) and the human factors study (Groner and Levin, 1992).

Water Problem

Of eight engineering considerations addressed in this project, the most significant is the potential for water damage to elevator system components inside the hoistway. During a building fire, water from sprinklers and fire hoses can damage electronic, electrical and mechanical components of the elevator system. Two potential solutions to the elevator shaft water problem are:

1. Use elevator system components that can function in a wet environment; and
2. Prevent water from entering the shaft.

Currently, many elevators operate outdoors on exterior walls of buildings with many of the system components exposed to rain, wind and extremes of temperature. Thus, it is technically feasible to build elevators with water-protected components which will operate during a fire. However, maintenance of such water-resistive components on elevators not exposed to the elements is a concern. For example, systems inadvertently repaired with non-water-resistive components can operate properly under normal conditions without indication of the improper parts.

Elevators can be constructed to prevent water entering the shaft by use of floors sloping away from the elevator door. Floor drains can be part of such an approach. This approach has the advantage of requiring almost no maintenance. Further research is needed to determine which approach to water protection for the elevator shaft is the most practical and cost-effective.

Calculation of Evacuation Time

The movement of people during a fire is complex, including use of some elevators and stairs by the fire service, some evacuation routes being out of use because of smoke or fire, and occupants going against the normal flow of people to rescue others. This flow is much more complicated than that which occurs during fire drills. Analysis of this complex flow was beyond the scope of the GSA Elevator Evacuation Project. However, a computer program, ELVAC, was developed to calculate the evacuation time by elevators during a fire drill. This idealized evacuation time is useful in comparing the relative evacuation time for different buildings.

The approach used in ELVAC is based on quitting time (outgoing) traffic calculations of Strakosch (1983). In ELVAC, the evacuation time, t_e , is

$$t_e = t_a + t_o + \frac{(1 + \eta)}{J} \sum_{j=1}^m t_{r,j}$$

where $t_{r,j}$ is the time for round trip, j ; m is the number of round trips; J is the number of elevators; η is the trip inefficiency; t_a is elevator evacuation start-up time; and t_o is the travel time from the elevator lobby to the outside or to another safe location. The round trip time depends on the travel time

of the elevator and on the number of people traveling in the elevator, as discussed later. The travel time from the elevator lobby to a safe location can be evaluated by conventional methods of people movement (i.e., Nelson and MacLennan [1988] or Pauls [1988]). The trip inefficiency accounts for trips to empty floors and trips to pick only a few stragglers.

The elevator evacuation start-up time is the time from activation to the start of the round trips that evacuate people. For automatic elevator operation, the computer considers that evacuation starts after all of the elevators have been moved to the discharge floor. For manual operation, the time for elevator operators to be alerted and then get to the elevators must be included in the start-up time.

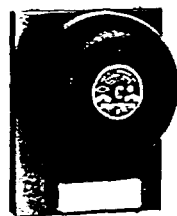
The round trip time consists of the standing time plus twice the travel time. The standing time is the sum of the time to open and close the elevator doors twice, the time for people to enter the elevator and the time for people to leave the elevator. Typically, elevator travel consists of constant acceleration motion, transitional acceleration motion, constant velocity motion, transitional deceleration motion, constant deceleration motion and leveling motion. The time for most of these motions are obtained from equations that can be found in most elementary physics texts. However, the transitional motions are estimated by an approximate equation and the leveling time is taken to be a constant.

Potential Applications

Four GSA buildings were selected to be analyzed as potential applications of elevator evacuation. The buildings were the Hoffman Building II in Alexandria, Virginia; the White Flint North Building in Bethesda, Maryland; the Jackson Federal Building in Seattle, Washington; and the General

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Safety Equipment

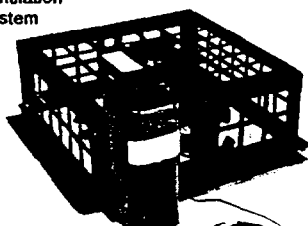


Alarm Bell w/Strobe



Smoke Detector Tester

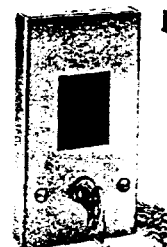
Door Keys



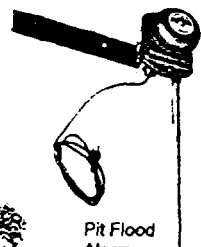
Stand-by
Emergency
Ventilation
System



Fire/Emergency
Signs



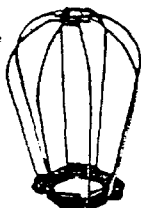
Emergency
Door Release



Pit Flood
Alarm



Fire Key Box



Lamp Guard

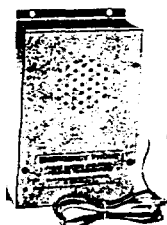


Pit Ladder



Hoistway
Access
Key Box

Emergency Phone



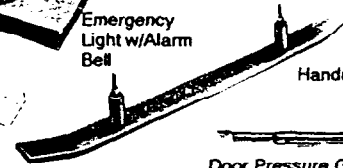
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Services Administration Building in Washington, DC. These buildings were selected in an attempt to study buildings of different heights, elevator capabilities and architectural characteristics.

Numerous ELVAC runs were made for each building to obtain a combination of stair and elevator evacuation that would minimize evacuation time. The evacuation times using stairs were calculated by conventional methods of people movement (i.e., Nelson and MacLennan [1988] or Pauls [1988]). Some general information about the buildings and the extent to which evacuation time could be reduced are shown in Table 1. The savings in evacuation time by using a combination of elevators and stairs over using only stairs ranged from 10% to 50%. It is concluded that the potential for reduced evacuation time is generally greater for taller buildings than for shorter buildings.

Discharge lobbies and floors must be able to handle the flow of people. Conventional methods of people movement were used to evaluate the extent to which the elevator lobbies and paths to the outside are sufficient. In the Hoffman Building and the White Flint Building, the discharge capacity was insufficient for the flow resulting from operation of all the elevators. Thus, evacuation calculations were done with a reduced number of elevators operating.

Staging Area Study

The staging area project was not about elevator evacuation, but it is included here because it is relevant to elevator evacuation. At the direction of the U.S. Congress, GSA modified six buildings for fire protection of persons with mobility disabilities. The two types of systems used were staging areas and horizontal separation. The staging areas are intended as spaces in which people with disabilities can safely wait during a fire. These staging areas are similar to the areas of refuge required in some applications by the implementation of the Americans with Disabilities Act (Department of Justice, 1991). Horizontal separation consists of one or more barriers which divide a floor into separate areas with the intent of restricting smoke and fire. These barriers include automatic closing doors.

The staging area project consisted of field tests, fire threat analysis and human behavior studies. A brief overview of the project is presented here. If more detailed information is desired, the reader is referred to Klote, Nelson, Deal and Levin (1992), and Levin and Groner (1992).

The spaces that were turned into staging areas include passenger elevator lobbies, service elevator lobbies, sections of corridors and rooms. The six buildings modified were the Veterans Administration Building, the Whipple Federal Office Building, the Toledo Federal Office Building, the Bemidji Federal Office Building, the Cohen Building and the Pension Building. Table 2 lists the spaces used as staging areas in each of these buildings, along with some other general information.

Field tests of the six GSA buildings were conducted, which determined leakage areas between staging areas and other building spaces. These areas were obtained by pressurization tests using the staging areas' own pressurization smoke control systems. Also, leakage areas of gaps around doors in barriers of horizontal separations were measured.

An essential step in evaluating the capability of the staging areas and related systems to fulfill the fire safety needs of persons with disabilities is the evaluation of the potential

fire threat that may be faced. The procedures used include the models and other evaluation features contained in the fire hazard analysis programs of FPETOOL (Nelson, 1990); the procedures outlined by Steckler (1989) for estimating the conditions developed by smoke flow through corridors; the smoke flow model ASCOS (Klote and Milke, 1992); a sprinkler fire suppression algorithm (Madrzykowski and Vetori, 1992); and the N-GAS Toxicity Model (Bukowski et al., 1989). Fires were selected so that, for each location, there would be: (1) a fire that would (if not suppressed) produce flashover in the given room or space being analyzed; (2) a fire that in the same space would approach but would not reach flashover; and (3) a smoldering fire. Analysis of estimated movement time to staging areas were made for able and disabled persons.

The following conclusions apply specifically to the installations investigated in six GSA buildings. Since these buildings represent a wide range of sizes, shapes, geographical locations and approaches to safety, it is believed that methods of analysis used in this paper are applicable to many other buildings. However, individual buildings will require individual engineering analysis.

1. Staging areas can be either a haven or a hazard. The difference is highly dependent on details of design, the type of fire exposure, outside wind and temperature conditions, and the capability and reliability of the smoke control pressurization system. Without pressurization, all staging areas are subject to lethal failure.

2. In many cases the persons most needing the staging area protection may be unable to reach that area before their pathways (corridors or aiseways) become lethal.

3. The organizational and human behavior problems involved in the use of staging areas are significantly more complex than those associated with the traditional total exit approach. There are no model programs or other guidance on how to use staging areas, and on what to expect when they are used. There is a distinct need for more research in this area.

4. The operation of a properly-designed sprinkler system eliminates the life threat to all occupants, regardless of their individual abilities, and can provide superior protection for people with disabilities, as compared to staging areas.

Human Considerations

Designing and installing elevators that can be used safely during a fire is only half the job. The elevators are part of an evacuation system that includes a security staff who can direct the evacuation and building occupants who must be willing to use the elevators. Failure to address all aspects of the system during the design phase can lead to problems that may be difficult and expensive to remedy, which is the normal consequence of ignoring vital aspects of any system during its design.

There are several obstacles to getting building occupants to use elevators in fire emergencies. First, there has been a 20-year campaign to teach people not to use elevators in fires. Secondly, occupants may not have confidence that the elevators will operate as planned. Also, people have strong needs to exert control over their own fate and relying on elevators decreases such control.

On the other hand, the use of elevators should be appealing for several reasons. People tend to leave buildings by

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Measurement:

Vibration: Acceleration -1.9 to 1.9g

Sound Level: Decibels 50 - 80 dB(A)

Microprocessor Based

Display: 4 Line by 20 Column LCD

Resolution: .001g (.0098 m/s²), .0322 ft/s²

Frequency Response: 0.1 - 45 Hz

Internal Time/Date Clock

Battery: Gel Cell, 100 hrs. per charge

OPERATIONS

VASE Software

Record Time: 10 to 180 seconds per recording

Data Output: Printer or ASCII File

System Requirements: DOS 3.3 or Higher

640K Ram, CGA

8088

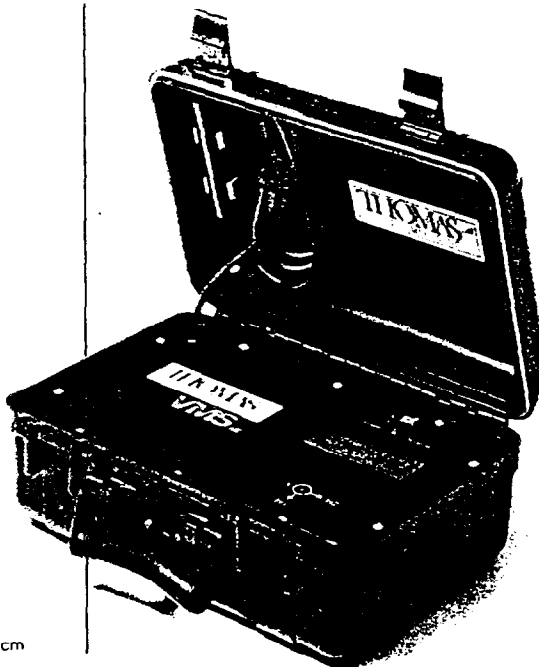
(286 min. recommended)

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L 35.5 cm x W 26.9 cm x H 16.5 cm

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FIRE EVACUATION

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the same route they used for entering: those who used elevators to arrive at their desired destination will tend to return by the same means. If the occupants are on an upper floor, the physical effort required to leave the building by stairs might encourage elevator use. The congestion on the stairs, especially if the evacuation is not phased by floor, might be very unpleasant.

Training the occupants is very important. Training sessions should address the fears of the occupants. It should be explained to the occupants how the system works. The need for priority access to stairs and elevators should be explained. Special features and subsystem backups that help assure the safety of those using elevators to evacuate the building should be discussed. In large buildings, potential congestion problems on the stairs should be described.

The training should also cover the required actions of those being trained. The occupants should be told how they will be informed regarding when and how to evacuate. The responsibility, if any, of occupants to assist other occupants with disabilities should be described. This information should also be given to all occupants in the form of a written fire emergency plan.

Concerns that the system will not work in a emergency will be a continuing problem. These concerns will be less intense in buildings that are generally well managed and well maintained. Good management engenders confidence. Up-to-date, written fire emergency plans will also help foster confidence.

The emergency team, including the security staff, must control and direct the evacuation whenever there is a phased evacuation or the elevators are used to evacuate some of the occupants. (Some of this function may be assumed by firefighters after their arrival. It is assumed that those near the fire will have evacuated or moved to a safe area prior to the arrival of the fire department.) There are two aspects of this responsibility.

There is a need for a command center to coordinate the evacuation. If there is a phased evacuation using stairs, the priorities for stair usage must be assigned. When elevators are used, the priority assignment of the elevators to floors must be made. If some of the general building population is to use elevators, it is likely that the assignment of occupants to elevators or stairs will be made by the control center, based on the location and severity of the fire. The dynamic nature of the fire emergency might require changes in priorities and assignments.

Varying degrees of automation are possible when coordinating the use of elevators to evacuate building occupants. At one extreme, the system could be fully automated, without the use of elevator operators; a computer program would determine the routing of the elevators. At the other extreme, the system could operate entirely under manual control. Control room coordinators would determine the routing and they would telephone instructions to elevator operators, using emergency phones. Each approach has its advantages and disadvantages. For example, automation permits immediate use of the elevators without waiting for the emergency operators to arrive. On the other hand, manual operation takes advantage of the ability of people to respond to unanticipated problems. The best balance between automation and manual operation would differ among buildings and might change as we gain experience. However, any automated portion of

the system should have manual backup. There is also a need for a group of monitors or wardens who will give direction and information directly to the building's occupants.

All those manning the control room, and all monitors and wardens, must be fully trained. This includes frequent refresher sessions because fires and fire drills usually are widely spaced in time, and skills and knowledge can be easily forgotten. A good training program will also add to the confidence that building occupants have in the system.

The system also must include a communication system to provide the control room with information and for the control room to give information, and instructions directly to the occupants or indirectly through the monitors and wardens. This communication system needs to be planned during the design phase of the building to avoid costly changes. This highlights the need to design the total evacuation system before the building is built or renovated.

An evacuation system might be designed so that only occupants who have disabilities may use the elevators during a fire emergency. Such a system would be simpler than one where some others will be directed to use the elevator. However, the need for system design, a control center, wardens, training, fire plans, etc., applies to both. While occupants with disabilities have little choice but to use the elevators, it is important to give them confidence that the elevators will provide a safe means of evacuation. The evacuation system cannot be deemed a success if they have serious doubts about their own safety in emergencies.

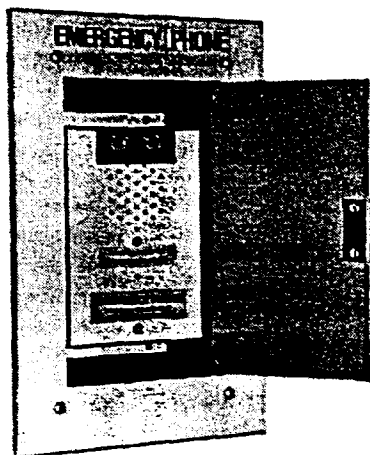
Industry Concerns

There is a common misconception that elevators cannot be used during building fires. However, firefighters use elevators, when appropriate, for evacuation and mobilization of personnel and equipment during fires as described in the ASME A17.1 Handbook (Donoghue, 1990). It may be a surprise to many people that elevators have been used for building evacuation in many fires. Occasionally, during hospital fires, elevators located far from the fire have been used for evacuation of non-ambulatory patients (for example, the St. Joseph's Hospital fire [Bryan and DiNenno, 1978]).

Elevators are not automatically taken out of service when there is a fire in a building. The elevator code, ASME A17.1 (ASME, 1990), requires that elevators only be taken out of service when a smoke detector in an elevator lobby or in the elevator machine room goes into alarm. When one of these detectors goes into alarm, the elevators go into what ASME A17.1 and firefighters refer to as Phase I Emergency Recall Operation. This operation consists of recalling the elevators to the discharge floor and opening the elevator doors. If the alarm received by the elevator system is from the discharge floor elevator lobby, the elevator is recalled to an alternate floor. There is no hazard to people continuing to use an elevator until Phase I is activated automatically, provided that the smoke detectors and associated hardware operate as intended. The fire department always has the option of activating Phase I manually if they need the elevators. If people were on the elevator and Phase I was activated, they would be transported nonstop to the above mentioned discharge floor.

Phase II Emergency In-Car Operation can be activated after Phase I recall is complete. Phase II operation places the car under the exclusive control of an operator in the elevator. In current practice, Phase II operation is exclusively used by firefighters. However, the ASME A17 Committee has recognized the need to use elevators in Phase II to evacuate

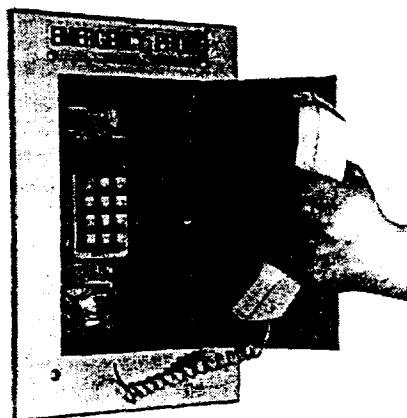
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people with disabilities in fire emergencies since the early 1980s. Accordingly, the elevator code (ASME, 1990) states that Phase II is "for use by trained emergency service personnel only." Thus, Phase II could be used by trained building personnel or by the fire service for evacuation of the disabled. Of course, any such elevator evacuation would need the cooperation and participation of the fire service.

There is concern with the environment the elevator is exposed to during a fire. There are problems with smoke, elevated temperature, water and reliable power. It is well-known that smoke can damage electronic components of elevator systems. Concerns with elevated temperature operation were discussed at the ASME Symposium on elevators and Fire (Robibero, 1991; Madison, 1991; Marchitto, 1991). During fire incidents elevator machine room HVAC is typically shut down. While the ASME A17 Committee is writing requirements to address a safe shutdown of elevator equipment due to high ambient temperatures, the A17 Committee has no direct control over elevator machine room heating and cooling requirements.

There are documented cases of power loss due to the fire incident. At the MGM Grand Hotel fire (ASME A17 Committee, 1984), the normal/standby power transfer switches, which were located some 20 floors above the fire, exploded. Electric power to the elevators was also reportedly lost in the early stages of the fire at the 1st Pennsylvania Bank Building in Philadelphia.

As previously stated, it is technically possible to build elevators with water-protected components. The question arises as to how these water-resistive components are to be tested. Currently, elevators are subject to a rigorous inspection and test procedure (ASME, 1990). The excellent safety record of elevator equipment is in part due to an ongoing program of assuring the equipment is properly maintained. Reliability is proven by testing for continued conformance with code requirements. However, it does not seem practical to test water resistance this way. To test water resistance the hoistway would have to be flooded with water or some kind of water spray would have to be used. Such tests have a significant probability of water leakage from the hoistway and resulting damage to the interior finishes and the structural, mechanical, electrical and fire protection systems. Thus water resistance testing does not seem practical.

One must consider that there are thousands of different elevator components that would have to be protected from water. The enclosures for these components are not universal from manufacturer to manufacturer. The enclosures from a single manufacturer even vary from system to system. Many of the components are subject to routine inspections and maintenance. Thus, the enclosures are routinely opened. If they were waterproof, a new gasket would probably be required every time the cover was removed. The logistics of stocking and supplying the necessary gasket is not practical.

Without some kind of test of water resistance, component could degrade or be damaged from years of use. When these components are in contact with water during a building fire, an elevator system failure is highly probable. Thus, preventing water from entering the elevator hoistway seems a preferable solution.

The operation of elevator evacuation for the general population is very complicated and automatic control for such

system also would be complicated. Validating such an automatic control algorithm would require development of new computer software for people movement simulations during fires. The complexity of this approach is a concern, because of the implications about successful operation. One concern is the potential for people to overload the elevator. Overloading, if detected before the car moves, would shut the car down at the floor. If not detected, it could cause the car to overspeed, actuating the car safeties. Passengers could be trapped in the car. Another concern is door reversal devices keeping the doors open when people obstruct the path of the closing doors.

A simpler approach would likely succeed. An elevator system for evacuation of the disabled only using manual operation under existing Phase II operation may be an appropriate starting point.

The longer the environment in which the elevator must operate is maintained in a normal state, the longer normal elevator service can be maintained. If smoke does penetrate that environment, the elevator will automatically go on Phase I Emergency Recall Operation. During normal operation, the newer elevator control systems will recognize the increased down traffic and down peak operation will be implemented.

Open Discussion

During the open discussion, the participants addressed the protection needed for elevator evacuation, elevator controls, the human behavior challenges, the water problem and future directions. Much was learned from this exchange. While there were no votes on specific issues, it seemed that the following points were agreed upon by most of the group.

System Concept

For an elevator evacuation system, enclosed elevator lobbies are needed to protect waiting persons from fire and smoke. The elevator evacuation system would include the elevator system, elevator lobbies, hoistway and machine room. This system needs to be protected from heat, smoke, water and loss of power. Even though protection from heat, smoke and loss of power are significant engineering challenges, these areas probably do not need research. However, the extent of the water problem is not known.

It was agreed that the fire protection community should have the ability to use such an elevator fire evacuation system as one of many tools (sprinklers, compartmentation, etc.) to protect life in new and remodeled buildings.

Water Problem

The New York City Fire Department and the ASME A17.1 Emergency Operations Committee are developing a test program to evaluate effects of water entering elevator hoistways. The goal of this program is to evaluate reliability of fire-fighter's service under conditions encountered during a fire. While the source of funding for this project is unknown, such an effort is needed as a first step to evaluate the extent of the water problem. Any evaluation of the water problem should take into account the presence of water in the hoistway indicates that water has probably been put on the fire. This would suppress the fire or extinguish it. In either case, the threat to life is considerably reduced. Consideration may be needed to taking elevators out of an evacuation mode if water is detected in the hoistway. It seems the water problem is the same for elevator systems used for evacuation of the disabled only and those used for evacuation of the general population. Further research is needed concerning the extent of the water problem, and potential solutions need to be developed and evaluated.

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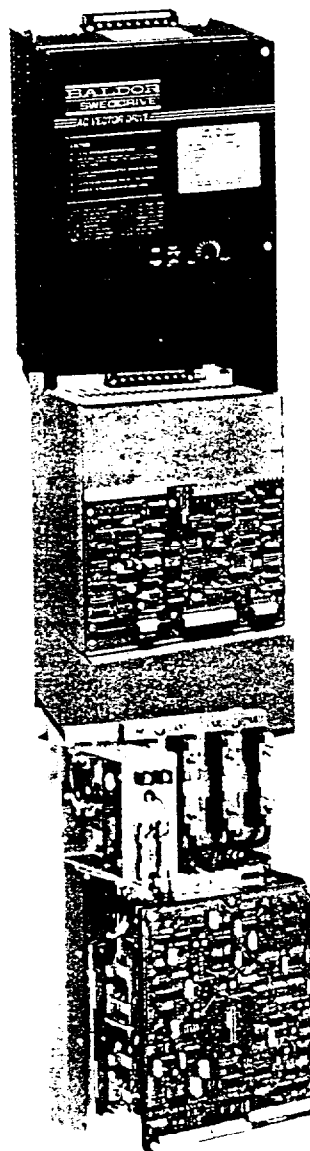
- Microprocessor based... accepts digital or analog input
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- 230, 380, or 460 VAC versions
- Suitable for geared or gearless machines
- "S" curve pattern generator embedded
- Programming keypad included aboard controller as standard
- UL listed
- Use with NEMA B, or NEMA D motors
- Baldor vector duty elevator motors available or;
- Use existing motor... simply add an encoder

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- Suitable for speeds to 100 FPM
- Ratings to 50 HP at 460 VAC
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- Electronic restart option available for fuseless models
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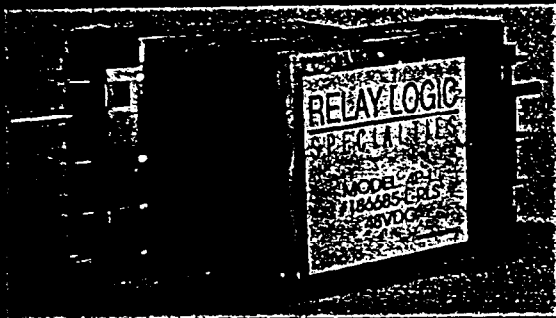
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FIRE EVACUATION Continued from overleaf

Manual and Automatic Controls

Both manual and automatic elevator controls are possible. Manual controls are much simpler and existing Phase II manual controls can be used for fire evacuation of the disabled. Automatic controls could be put into an evacuation mode without waiting for a person to operate the elevator. This advantage would be important for elevator evacuation of the general population but probably not for elevator evacuation of the disabled. Because of the complexity of automatic controls, there is a concern about controls malfunctioning and trapping passengers. Another concern is overcrowding of the car so it does not move or causes a safety activation, trapping passengers.

Using manual controls for Phase II, the small number of people with disabilities anticipated in most buildings could be evacuated from floors near the fire quickly. Because of the complex movement of people during fire emergencies, further research is needed to develop and evaluate the algorithms needed for automatic control of the general population.

Sprinklered and Unsprinklered Buildings

Much of the discussion and thoughts were about elevator evacuation in sprinklered buildings. Considering that most new buildings are sprinklered, this seems appropriate. However, the idea that development of elevator evacuation should be limited to sprinklered buildings is not appropriate.

There is a considerable stock of unsprinklered buildings in the United States. If elevator evacuation is developed for sprinklered buildings, it is likely that it will be considered for some of the unsprinklered buildings. It was generally agreed that the levels of protection for elevator evacuation systems should be higher in unsprinklered buildings than in sprinklered buildings. If the development of elevator evacuation were limited to sprinklered buildings, then designers and code officials would have no guidance in dealing with unsprinklered buildings. Thus, unsprinklered buildings need to be included in the development of elevator evacuation.

Institutional Challenges

If a generally-accepted elevator evacuation system is developed, it will require the involvement of many institutions and organizations (including the model codes, NFPA, ASME A17 and the fire service). Codes and standards will need to be modified to accept the new system. Involvement of the fire service will be essential to assure that the system meets their needs.

Operational Challenges

If elevator evacuation systems are developed, operation of these systems will include challenges of planning, training and maintenance. These challenges are significantly more complex for elevator evacuation of the general population than they are for only people with disabilities.

Future Direction

Application of elevator evacuation for the disabled population only is much simpler than for the general population and is the next logical step. Such an application could consist of modifying an existing building or incorporating elevator evacuation into a new design. Such a project would need the sincere cooperation of owners, designers, contractors, code officials and the fire service. Additional information about water protection is needed and research about water protection could be part of the project. Design of the project should include input of human behavior experts, and human behavior tests of the system during fire drills is needed t

ensure that people can use the system. Acceptance tests are needed to determine that the system physically performs as envisioned. Based on what is learned in this step, an application for the general population could follow.

Summary

a. The fire protection community should have the ability to use elevators for fire evacuation as one of many tools (sprinklers, compartmentation, etc.) to protect life in new and remodeled buildings. In order for an elevator to be used for evacuation, it should be protected from heat, smoke and water. Phase II operation can be used for fire evacuation.

b. Further research concerning the extent of the water problem, and development and evaluation of potential solutions is needed.

c. While elevator evacuation technology may be primarily aimed at sprinklered buildings, information about elevator protection in unsprinklered buildings is also needed.

d. Application of elevator evacuation for the disabled only is much simpler than for the general population, and is the next logical step. Based on what is learned in this step, an application for the general population could follow. □

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FOOTNOTE

* NFPA 72 (Protective Signaling Systems) includes requirements for emergency voice communication systems which should be used whenever phased evacuation is planned. Such systems include a protected command center from which both occupant evacuation and fire department operation can be controlled.

Dr. John Klote, Project Leader for Large Scale Smoke Movement at the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland, is responsible for research in smoke control, smoke movement, fire safety of refuge areas and fire emergency use of elevators. Techniques used by Dr. Klote include full-scale fire and scale model experiments, field tests and computer simulations. The primary author of the book *Design of Smoke Management Systems* and over 40 other papers on various aspects of fire protection engineering, he is a registered professional engineer with a doctorate in mechanical engineering. Before working for NIST, he had 11 years experience in design, specifications and cost engineering at the Naval Facilities Engineering Command.



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Bernard Levin is a psychologist specializing in actions of building occupant during emergencies, especially fires. He is concerned with design of emergency procedures and equipment to assure they are consistent with the capabilities and normal responses of the occupants. After 30 years at NIST, Dr. Levin is now a private consultant in Rockville, Maryland.

Norman Groner has 15 years experience researching how people can better prevent, mitigate and recover from fires and other emergency situations — and how regulations and emergency planning affect (sometimes adversely) the people and organizations they are intended to protect. Dr. Groner is author of several manuals and research articles.